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Final Report

Risø National Laboratory, Roskilde, Denmark
August 1996

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APAS-project: Feasibility Studies on Combined Wind Diesel Desalination in Greece and Spain

Final Report

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August 1996

Abstract

The present report is the summary report for the APAS-project '*Feasibility Studies on Combined Wind Diesel Desalination in Greece and Spain*' supported by the European Commission, DG XII, under contract no. RENA-CT94-0006.

The project consists of two feasibility studies: Paros, Greece and Menorca, Spain. The purpose of the studies is to investigate the feasibility of combining wind energy and fresh water production in diesel powered grids. The results of the two studies are in the reports: Risø-I-1042 (Paros) and Risø-I-1043 (Menorca).

The major finding is that there are technical and economical benefits from combining wind energy with desalination plants. The penetration level can be increased without increase in the amount of dumped wind energy and a large proportion of the energy required by the desalination plant can be covered by wind energy.

The wind resources in Paros are very good. A publicly or privately owned system that combines wind energy and desalination units is economically very attractive because of the legal framework concerning renewable energy in Greece. Efforts are underway to implement a system by combining private and public investors.

In Menorca the wind resources are not as attractive as in Paros and the available energy cheaper. Wind energy is therefore not feasibible when only avoided fuel costs are considered. However, due to environmental concerns the local authorities and utility are interested in an integrated wind diesel desalination system. Another reason for that interest is a wish to participate in the development of such systems. Support for such a system is sought mainly through EU.

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Contents

1 Introduction

The present report is the summary report for the APAS-project '*Feasibility Studies on Combined Wind Diesel Desalination in Greece and Spain*' supported by the European Commission, DG XII, under contract no. RENA-CT94-0006.

Risø National Laboratory (DK) is the co-ordinater of the project. CRES (GR) and CIEMAT (ES) are contractors and responsible for the contacts to the local authorities in Paros resp. Menorca and other relevant people in Greece resp. Spain. Darup Associates and EuroScan Services are subcontractors to Risø on performance estimation and implementation issues.

The project consists of two feasibility studies: Paros, Greece and Menorca, Spain. The purpose of the studies is to investigate the feasibility of combining wind energy and fresh water production in diesel powered grids. The results of the two studies are in the reports: Risø-I-1042 (Paros) and Risø-I-1043 (Menorca). Also investigated are general implementation issues in Greece and Spain like financing and organisation.

The studies have been carried out with help from the local authorities in both Paros and Menorca. They have paricipated in the definition and discussion of the various possibilities regarding system configurations, financing and organisation and have provided parts of the necessary data.

In both Paros and Menorca there is lack of water as is the case in several other islands in the Mediterranean and through out the world. One way of solving this problem is through sea water desalination. There are several applicable technologies for this like reverse osmosis (RO), mechanical vapour compression (MVC) and multi effect distillation (MED). RO and MVC requires electric energy as the main source whereas MED is driven by thermal energy. The efficiency of RO and MVC is much higher than that of MED so for larger amounts of water RO and MVC are most applicable.

In order to cover the energy in an environmental friendly way renewable energy should by combined with the water production. In the current project wind energy is considered. Different aspects of the integration of both wind energy and desalination in autonomous diesel powered power supply systems are studied in order to find suitable solutions for the two islands.

In the evaluation of the different options both technical, economic and for Paros also financial and organisational issues are considered. Diesel operation limits and other performance limiting factors for the wind turbines are taken into account in the simulation of the power system. The output of the these simulations are used for the economic and financial calculations. Financing and organisation are discussed with the local authorities, local utilities, manufactorers and potential investors.

2 Executive Summary

2.1 Paros Case

Paros is one of the Cyclades in Greece. Its main source of income is tourism. There is one power station with a total installed capacity of 30.6 MW, while a new unit of 10 MW is expected in service in 1996. The power station also covers the neighbouring island, Naxos. Due to the well developed tourism there is a strong seasonal dependence of both the electric and water demand. All the generating units are diesel gensets. The size range is 2-10 MW.

The water demand is currently covered by ground water. The capacity cannot cover the demand during high season and the average water demand is also above the long term capacity of the fresh water resources of the island.

The main concern of the authorities of the island is fresh water and not power capacity.

As a resuylt of the studies the recommended solution for Paros is 3-4.5 MW wind farm and a 2400 m^3/24h mechanical vapour compression desalination unit. This will result in a wind energy penetration level of 11-16%. For the larger wind farm some of the wind energy has to be dumped in order to keep the diesel gensets within their allowed operating range. In Table 1 are the main figures regarding inclusion of wind energy in the Paros grid.

Table 1 Key figures of Paros Scenarios

	3 MW wind farm	4.5 MW wind farm
Water prod. [m3/24h]	2280	2280
Fuel Saved [%]	10	15
Wind Energy Utilized [%]	99	95
Penetration Level [%]	11.0	15.8

The desalination plant capacity is approximately the size of the average consumption. The current use of ground water can therefore be minimized and used only in peak load situations. This will relieve the ground water resources and make room for the increase in consumption requires by the growing tourism.

In Greece there exists a legal framework for renewable energy (law no. 2244/94). According to this framework the Public Power Corporation (PPC) is obliged to buy the energy from renewable energy sources and the tariffs are set. The tariffs depends on several conditions e.g. ownership and auto/independent power producer status. The most attractive option in this framework is independent producer, i.e the wind farm and desalination plant are publicly or privately owned and all the power from the wind farm is sold to PPC and all the power consumed by the desalination plant is bought from PPC.

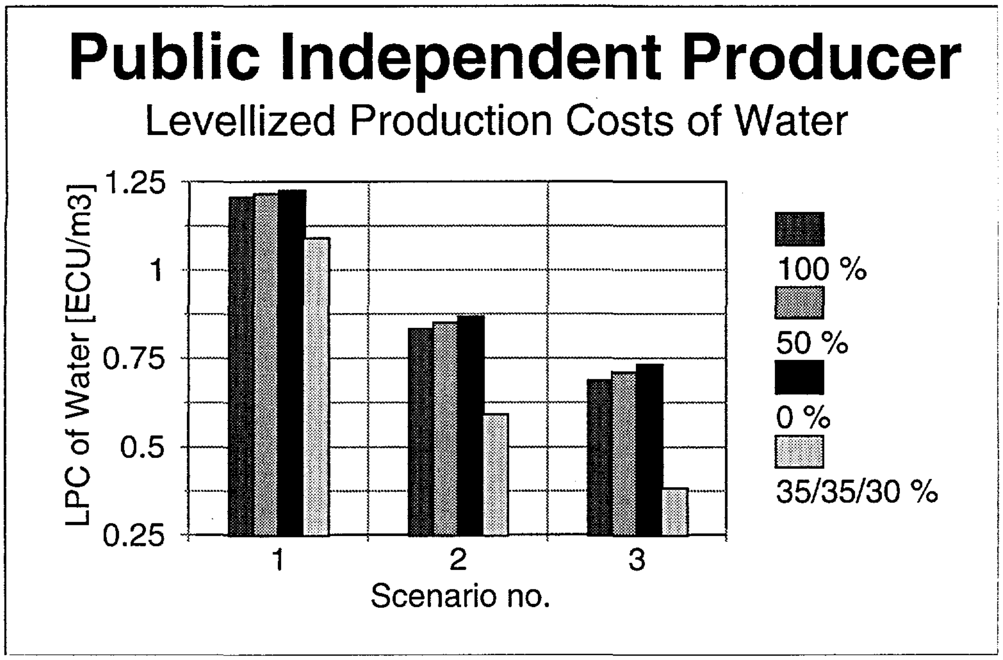

Figure 1 Publicly owned plant (Independent Producer): Internal Rate of Return of the investment for the defined scenarios. Financed by 100 % down payment, 50 % down payment/50 % loan and 100 % loan, 35 % grant/35 % loan/30 % down payment

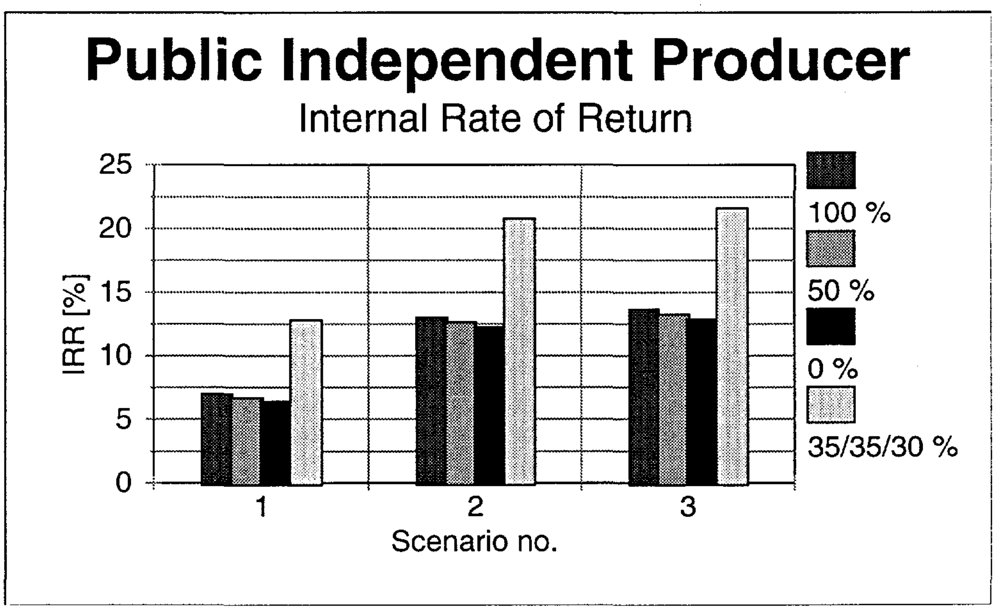

Figure 2 Publicly owned plant (Independent Producer): Internal Rate of Return of the investment for the defined scenarios. Financed by 100 % down payment, 50 % down payment/50 % loan and 100 % loan, 35 % grant/35 % loan/30 % down payment

It is seen from the figures that the inclusion of a wind farm significantly reduces the cost of water and if the case that includes only the desalination unit is taken as base, the internal rate of returns in the two cases that includes wind turbines are fairly high.

A 3-4.5 MW wind farm and a 2400 $m^3/24h$ MVC desalination plant are relatively complex installations that requires skilled workers for their maintenance. In Paros the local authorities do not possess these skills, and it is therefore necessary to establish an organisation that can have the responsibility of operating and maintaining the total installation. One of the options for operating the system is to have a capable company as partner. In the implementation investigations this option has been found to be one of the more attractive. Another option is build-own-operate-transfer. One of these two options is recommended. A final decision can only be reached after negotiations between the local authorities, potential investors and potential operators.

The conclusion is that the installation of a wind farm and a MVC desalination unit is an attractive solution for solving the water shortage problem of Paros. The main obstacle now is to find a way of organizing the project that satifies all the involved parties: local authorities, investors and operators. Investigations to solve this continues.

2.2 Menorca Case

Menorca is an island in the Balears in the Mediterranean south of the mainland of Spain. The main source of income is tourism but there is also an agricultural sector.

The power system of Menorca is connected to Mallorca through an AC sea cable connection. The power station is situated in Mahon, the principle town of Menorca. The generating capacity consists of 3*15.8 MW diesel units and two gas turbines for peak load coverage. The main generating capacity of Mallorca is coal fired thermal power plants.

The water demand is currently covered by ground water and the capacity is at the moment adequate. However, in the near future there will be a need for water that cannot be covered by ground water. Forecasts estimate that the need for desalinated water will be 5000 $m^3/24h$ in year 2000.

The cost of energy from the conventional power plants in Menorca at the current fuel prices and the moderate wind resources does that wind energy is not economical feasible at the moment. The cost of energy is in Table 2. The cost of wind energy is 60 ECU/MWh.

Table 2 Marginal costs of energy in Menorca dependent of fuel type

	Coal	Heavy Fuel	Weighted Average
Cost of Energy [ECU/MWh]	14	33	28

However, the local authorities and the utility are both interested in renewable energy in order to develope a sustainable society and to contribute to the development of technology that make such a development possible.

Because of that interest a system that integrates wind turbines, diesel engines and desalination units, a socalled wind diesel desalination (WDD) system, has been studied. The main results including the cost of wind energy energy is in Table 3.

Table 3 Results for stand alone wind diesel desalination systems incl. MVC desalination plant (all figures are levelized)

Diesel genset capacity [kW]	500	500
Desalination unit capacity [m^3/24h]	1000	1000
Wind turbine capacity [kW]	300	600
Cost of wind energy [ECU/MWh]	60	69
Cost of water (MVC) [ECU/m^3]	1.30	1.43
Penetration level [%]	15	25
Utilized wind energy [%]	100	84

The local authorities are concerned about the environment and are therefore positive towards renewable energy and therefore also wind energy. The local authorities prefer solutions that do not include diesel engines.

It is recommended that the posibilities for installing wind turbines in connection with desalination plants are further investigated. This will contribute to the water production, introduce wind energy on the island and contribute to a sustainable development on the island.

2.3 Benefits from Combining Wind and Desalination

One of the main reasons for limiting the penetration level in wind diesel systems is to keep the diesel units' operating conditions within the prescribed range and at the same time not dumping excessive amounts of wind energy.

Inclusion of desalinations plants in a wind diesel system increases the the amount of wind energy that can be absorbed and due to the constant and schedulable consumption of such a plant this increases the penetration level. This means that a relative large amount of the energy required by the desalination unit can be covered be wind energy, [1, 2].

As it is shown in the case of Paros combining wind energy and desalination can lower the cost of water. In the Paros case this is true for the financial case and almost for the economic case, since the IRR of the wind energy investment in the economic calculations (avoided fuel cost) is approx. 7%. The legal framework in Greece makes the inclusion of wind energy very attractive also for water production.

2.4 Implementation and Financing Issues

It must be stressed that general recommendations may change rapidly due to the fact that the "WDD sector" is in it´s initial stages, where new experiences can change the picture.

It must also be kept in mind that in this study focus has been on potential WDD project initiatives in a relatively small scale for smaller islands. Other conclusions might be drawn for bigger WDD project initiatives for big communities. On the other hand it seems to be more reasonable and less risky to start up with smaller initiatives. Therefore it does not seem likely that big WDD project projects will be carried out in this initial stage of development.

Using the results from the analysis above the following models for implementation and development of WDD systems are proposed:

A.Implementation context:
In an implementation context WDD systems shall be defined as desalination systems using wind turbines as a tool of making the costs of water production lower.

As a consequense of this approach the WDD systems focused on in an implementation context shall be technical systems, where the desalination system can be seen as an independent part (investment) and the wind turbines can be seen as an independent part (investment).

The ownership and the organisational structures behind the desalination system and the wind turbines are integrated/common. This approach makes it possible to optimize the outputs of the 2 elements together technically and economically.

The EU Structural Fond must in the future specifically target promotion of WDD systems.

B.Development and demonstration:
There is a need of demonstrating and developing technical and energical more optimized WDD concepts, e.g. the concept of utilizing the surplus heat from diesel generators together with electricity from wind turbines for integrated desalination and water production.

Also the strategy of utilising desalination systems for high wind energy penetration should be demonstrated and developed.

2.5 Development Perspectives

The development of decentralized power supply system with large amounts of renewable energy is one of the key issues in the future in order to ensure a sustainable development.

As a step in that direction is the development and implementation of wind diesel systems. The wind diesel technology is now at a stage where successful demonstration is very important. Wind diesel desalination systems is a very attractive way of introducing the technology since there often is both a lack of potable water and energy and the cost of energy makes wind energy competive. It is very important for these demonstration systems that they are successful. For the first systems only proven technology should be chosen and the locations should be with a well developed infrastructure.

For the future more advanced systems should be developed. These systems should be more integrated taking advantage of the diversity of renewable energy sources and also have means for utilisation of surplus energy in a more advanced way.

2.6 Conclusions

The project has conducted two feasibility studies on combined wind energy and desalination in diesel powered grids.

The study in Paros has shown that from a financial point of view is a combined wind desalination system is very attractive. The wind resources in Paros are very good and there is a big need for potable water. A system with 3-4.5 MW wind farm and 2400 m^3/24h desalination plant is recommended. Investigations have shown that there is a great interest amoung potential investors for such systems but also that there are problems to solve regarding the organisation of such a project.

The situation in Menorca is different due to the less favourable wind resources and the cheaper energy. In Menorca wind energy is not feasible when only avoided fuel costs are taken into account. However, there is concern about the environment at the local authorities and there is a great interest at the local utility to contribute to the developement of renewable energy systems. A combined wind diesel desalination system for demonstration purposes (as well as water supply) is therefore recommended because the infrastructure is very well developed at the island.

A the more general level it has been found that the technology for combined wind diesel desalination systems is available and ready for demonstration and that there are benefits from combining wind and desalination in diesel powered supply systems. The main advantage is the increased penetration level of wind energy that leads to decreased cost of water.

During the implementation and financing investigations it has been found that there is interest amoung potential financers for such systems. Their main concerns are insecurity with the technology and from operation & maintenance of the systems due to the lack of infrastructure at many of the attractive locations. One of the more promising concepts are build-own-operate which can be one of the ways to reduce the risk for possible investors.

At this stage of the development it would be very beneficial to have several demonstration projects that could create a positive track record and through that create a market.

3 Activities in the Project

The main activities in the project have been the execution of two feasibility studies.

There have been project meetings at:
1st Contractors meeting, Greece, Feb 1995
Plenary meeting, first mission, Menorca, Feb 1995
First mission, Paros, April 1995
Plenary meeting, Risø, June 1995
Second Mission, Paros, Oct 1995
2nd Contractors meeting, work meeting, Venice, Nov 1995
Round table discussion, Athens, Dec 1995
Second mission, Menorca, Mar 1996

There have apart from been several meeting with manufacturers and potential investors.

The project has produced three papers:
Contractors meeting, Venice, Nov 1996, [3]
EUWEC'96, Gothenborg, May, 1996, [4]
Mediterranean Conference on Renewable Energy Sources for Water Production, Santorini, June 10-12, 1996, [5]

The project has also produced contributions to the interaction scheme within the APAS programme.

4 General Technical and Economical Results

4.1 Description of Method

The method for assessing the performance of the system consists of three major parts: Data for the system, a technical/economic model and relevant scenarios. Data for the location being investigated including power system, data wind data, load data etc. are collected and used as input for the logistic simulation model. The power system performance is simulated in logistic terms for various scenarios. The output of this technical simulation is used to establish technical performance limits in terms of e.g penetration level and to calculate the economic consequences of installing wind turbines and desalination units. In the Paros case the output of the technical simulations has also been used to calculate financial performance of the system considered.

The key issues involved are the data collection and the definition of relevant scenarios.

4.2 System Modelling

The modelling of the power system is done using the logistic wind diesel simulation model, WINSYS, developed at Risø, [6]. WINSYS has been extended to handle both thermal and electric desalination units. WINSYS simulates the performance of a given power supply system (primary based on diesel units) and its response to inclusion of wind energy. It is a combined statistic/time series based model. Several diesel units can be included in the simulation with their fuel consumption curves and other operating characteristics. The model handles diesel scheduling. When a simulation is done both the results with and without wind farm are calculated. The model calculates e.g. fuel consumption, wind energy production, utilized wind energy, penetration level and thermal and electric fresh water production. Also a part of the model is the economic calculations based on the technical results. This part is based on the IEA recommended pratice for calculation of costs of wind energy, [7]. The outputs are including IRR of wind turbine investment, cost of energy and cost of water. All the results are levelized. For the financial calculations another spreadsheet model, INVESTOR, has been developed. This takes into account the several of the options in the legal framework regarding renewable energy in Greece.

Examples on input and output from WINSYS are in the two feasibility reports, [1, 2]. Examples of INVESTOR are in [1].

4.3 Benefits from Combining Wind and Desalination

Development of decentralized power supply systems with large amounts of renewable energy is one of the key issues in R&D in future energy technologies. The requirements to these systems in terms of power quality and stability are the same as to the current power supply system but they should integrate different renewable energy sources up to 100%. One of the major obstacles to accomplish this is the fluctuating nature of many of the renewable energy sources.

In a wind diesel system the fluctuating wind makes it very difficult to obtain high levels of penetration at low costs. Even at low penetration levels the operating constraints of the diesel units can make it necessary to dump wind energy. These situations can occur when the consumer load is low and the wind speed is high.

At many of the locations where the inclusion of wind energy in diesel power grids is attractive there is also a lack of water. Production of potable water requires energy. This energy can be either mainly thermal or electric. Thermal energy in a wind diesel system can be either waste heat from the diesel units or surplus wind energy. Usually it is economic attractive to utilize the waste heat for water prodution eventhough the energy efficiency for such units is low, for smaller units it is 600-750 kWh/m^3. For larger amounts of water more energy efficient technologies has to be applied. This can be reverse osmosis (RO) or mechanical vapour compression (MVC). These technologies are much more efficient requiring only approx. 10

kWh/m^3. RO requires less energy than MVC but is more fragile and requires more operating and maintenance skills. It would be very desirable if the energy required by these units could be supplied by renewable sources.

In the current study the combination of wind energy and desalination has been studied.

By including a electric desalination unit in the system the minimum load of the system is increased. This allows for an increase in the capacity of the wind farm that can be connected to the grid with out dumping more wind energy. The increase in capacity is slightly higher than the average amount energy consumed by the desalination units. The result is an increase in penetration level in the system. That is not only can wind energy cover the same percentage of the energy demand but the inclusion of the desalination unit makes it possible to increase the percentage covered by wind energy without dumping more wind energy. This one of the main advantages of combining wind and desalination.

The main advantage for the water production is that a large amount of the desalination units energy demand is covered by wind energy. This also means that if wind energy is competetive the cost of water is lowered by the inclusion of wind energy.

5 General Implementation and Financing Issues

5.1 Introduction

The scope of this chapter is to discuss how WDD systems can be implemented, including financing of WDD systems. Some of the findings are made within this project some are the results of general discussions with manufacturers, investors etc.

General aspects about implementation including financing is described.

5.2 Motivations for implementing WDD systems

Basicly WDD systems comprises of 3 main elements concerning outputs:

A.
Production of drinking water.

B.
Production of electricity from wind turbines and diesel generators.

C.
Surplus heat deriving from diesel generators.

Motivations for establishing WDD systems are connected to the 3 outputs mentioned.

5.2.1 Need of water

The need for water is growing due to different reasons. The general improvement of living conditions means a higher consumption of water per person. Industrialization can in regions induce a higher water consumption. In other regions a growing tourist sector can give rise to a growing demand of water.

Especially in the Southern part of Europe the growing consumption of water can give rise to an unsustainable situation concerning supply of drinking water. Typically the ground water sources are being over exploited.

The new and growing demands for water, e.g. for house holds and for the tourist sector, can cause conflicts between different groups and interests of water use. Typically there can be a conflict between the agricultural sector using water for irrigation and other sectors. In a number of places the tourist sector and the house holds are restricted in their use of water, e.g. for toilet flush. In other places the agricultural sector is restricted in production due to lack of water.

In some regions draughts are causing many problems giving a need of supplementary water supply than the traditional ones.

Many islands in Southern Europe import by boat drinking water from the main land although the costs for this water supply can be rather high. This shows that in many places there is a growing need for production of drinking water from desalination of sea water or other water sources.

Supply of water is normally a responsibility of the municipal authorities. This means that the motivation for providing additional water production from WDD systems is coming from local municipal authorities. In some cases a local big consumer of water, e.g. an industry, has an interest in having additional supply of water.

As it has been demonstrated above, wind turbines can improve the profitability of desalination, due to the fact that it may be profitable to produce electricity from wind turbines.

The bigger communities, such as towns or cities, have potentially the organisational and economic capacity of investing in WDD systems. But in these cases other possibilities of supplementary water supplies are typicaly used, such as establishing new pipe systems for water supply from water sources far away in mountains or similar.

Another problem for municipalities concerning the involvement in establishing WDD systems can be the production of electricity, which normally is a responsability of specific electricity utilities.

A general conclusion concerning motivation for local municipal water supply utilities must be that in dry islands and similar places there is a local motivation for establishing WDD systems for water production. But in the present situation it can not be expected that the municipal water supply utilities will play a very active role in initiating WDD systems.

If WDD systems are becoming more well known and demonstrated sucessfully, it can be expected that the local municipal water utilities will play a more active role in initiating WDD systems. In such a situation WDD systems will be considered to be part of the conventional water supply systems that is commonly used.

5.2.2 Need and production of electricity:

From WDD systems is produced electricity to be sold to the grid or (partly) used for desalination in the desalination system. Integration of a desalination system as an electricity consuming component in the overall electricity system can be used as a tool for increasing the wind penetration in the overall electricity system, as described above. If there is a motivation for establishing wind turbines for electricity production, combination with water production from desalination can be a positive factor.

In general the need for electricity is not a limiting factor for local development. This means that the motivation for establishing electricity production from WDD systems is basicly a question of using the wind turbines as a profitable way of producing electricity. Either as a profitable way of producing electricity to a desalination plant and thereby improve the economy of the desalination system - or as a way of improving the penetration of (profitable) electricity production from wind turbines.

A WDD system has a certain degree of technical complexity, and the organisation behind WDD system needs to have a capacity to be able to handle the WDD systems. This means that it must be expected that initiatives for WDD systems from a motivation of electricity production first of all will come from developers and investors or electricity companies, which will use wind turbines as a profitable way of producing electricity.

5.2.3 Utilization of surplus heat from diesel engines

There is a potential for using the surplus heat from diesel generators for desalination through evaporation techniques. In general this opportunity has not been used although it is a proven technology.

In several cases the power utilities are by law not permitted to go into water production through desalination. The other possibility of the power utilities selling/delivering the produced surplus heat to desalination company has not been used in practise up till now. There can be several reason for that, one of them setting the price for surplus heat.

5.2.4 Commercial motivation for establishing WDD systems

With the growing market for producing water from desalination systems combined with the possibility of using wind turbines as a way of reducing the cost of water from desalination systems - and the potential of using desalination systems as a way of increasing (profitable) wind penetration - developers and investors has a potential interest in establishing WDD systems.

5.2.5 Motivated partners must be identified

If WDD systems shall be established, motivated and capable partners must be identified. The complexity of the WDD systems concerning outputs, the traditions for public regulations of electricity and water production etc. can make it difficult to identify such partners. This is a problem in itself.

Therefore efforts must be made in identifying potential developers of WDD systems, and efforts must be made in motivating these potential partners in involvement in establishing WDD systems.

5.3 Organizing establishment of WDD systems

5.3.1 General comments

Organisation of the establishment of WDD systems must be seen in coherence with the technical solutions. This means that the implementation potential of a certain economic-technical WDD solution can not only be evaluated through a economic-technical evaluation. Also the organisational aspects must be included.

WDD solutions are not well known. This means that partners involved in developing WDD projects have a tendency of being hesitant of involvement. If this aspect is combined with a complicated organisational structure around establishment of the WDD systems with a number of different partners involved the chance for success is reduced. As example a WDD solution based on utilization of surplus heat from an existing diesel machine owned by the electric utilities has a bad chance of being realized because the power utilities have a difficulty in deciding about the conditions for selling surplus heat, decisions of who should pay for the extra installation etc.

It is important that the buyers of water and electricity have identified their interest as buyers, and what they want to pay. In some cases the conditions for selling electricity is defined through central regulations making it more simple to agree about the conditions.

In general central regulations concerning energy production from wind turbines, utilization of surplus heat from electricity produced from diesel generators, principles for sale of water from desalination plants etc. makes it more easy to establish WDD plants, because the conditions are more well known for the partners involved, and it is more easy to negotiate terms for establishing the WDD plants.

5.3.2 Local community ownership

The local community, typical the local municipality owning the water supply system, is a partner with a primary motivation for establishing a desalination plant for water production, e.g. a WDD system.

But the local communities with the need of additional water supply will typically be small communities, which do not have the technical or organisational capacity of establishing a WDD system. Also because they do not have the tradition of working with "frontier technologies" such as WDD systems.

In general a realistic role for the local communities, typically the municipality, will be to buy the water produced from the WDD plants. This is the case at the moment, where WDD systems are not widely deployed.

In the case of municipalities owning the water supply system there is also an element of policy included, in the sense that in many cases the water supply company do not charge the long term marginal costs of water, e.g. including the costs of medium and long term detoriation of the water resource. This again means that it can be difficult to have the municipal water suppliers accepting a realistic price of water from WDD systems.

5.3.3 Ownership by power utilities

Utilities producing electricity is an organisation, which is familar with dealing with technology and operation of technology. There fore power utilities have potentially the technical and organisational capacity of owning and operating WDD systems - or DD systems utilizing the surplus heat from diesel generators for generating water.

In general the power utilities have not in practise played an active role in establishing WDD or DD systems. The fact that they have not established DD systems indicate that there seems in general not to be a motivation from the power utilities of involvement in producing and selling water.

There can many reasons for this: Overall national regulations can prevent electricity utilities of involvement in areas outside of electricity production. Power utilities in many cases have a monopoly in producing electricity meaning that they have no motivation in seeking new areas of operation. There can be a fear of mixing up electricity production with other activities, e.g. installing desalination equipment inside or in connection to the electricity producing plant, fearing that this additional element can diturb the basic electricity production.

Power utilities in many cases are also reluctant of involvement in establishing wind turbines for electricity production. In the present situation it can not be expected that power utilities will play an active role in establishing WDD systems.

On the other hand modern and market oriented power utilities will see that there is a potential market for the electricity utilities of selling water and thereby expanding the fields of operation. In this case there is a potential that the electric utility will play an active role in establishing WDD systems - in areas with a good wind potential.

5.3.4 Private developers establishing WDD-systems

As mentioned above the demand for water is growing. In areas with shortage of ground water or other natural sources of water supply this means, that there is a potential market for selling water from desalination plants. In areas with a good wind potential the WDD concept can be economically attractive as technological concept for producing water. This means that establishing WDD systems for water (and electricity) production is a potentially interesting field of activity for private developers and investors.

In this connection one of the crucial points for private developers is the price of water which can be achieved for the water produced from the desalination systems. Another important aspect is, whether it is political acceptable for local communities to be dependent of a private producer in such a vital area for the local community as water supply or not. One of the ways of dealing with this issue is to have long term contracts for delivering water to the local community. Another solution can be local community co-ownership to the WDD system. These solutions can serve to give the local community a security of supply of water on longtime defined conditions.

The BOOT-concept (build-own-operate-transfer) gives the local community the ownership of the WDD plant after a period of time and thereby ensures the long term interests of the local community.

Private developers can as examples be: Investors looking for attractive investments, suppliers of WDD systems or main elements of the WDD systems such as wind turbines or desalination systems, companies with interests in servicing WDD plants etc.

5.3.5 Mixed ownership of WDD systems

If WDD projects shall have success, it is necessary that a number of different partners can act positively together. Typically these partners can be: The local community/municipality - the suppliers of the WDD system - (local) companies involved in servicing - developers and the investors behind the developers - and eventually the power utilities.

A model of ownership is a mixed ownership with involvement of all or some of the partners mentioned above. It is important in relation to utilization of such a model that it is clearly defined, who has the final responsability and what is the influence of the other partners. The advantage of the mixed ownership model is that all/the most relevant partners are represented as owners and thereby share a part of the responsability and interest of making the WDD system function successfully. In this context it is important to develop concepts that the partners are rewarded economically, if the WDD plant is functioning successfully.

5.4 Operation of WDD systems

5.4.1 General comments

It is vital for the success of establishing technical systems that the operation of the systems can be handled professionally and with full reliability. There are many examples, e.g. from installing wind turbines in countries with no traditions of having modern wind turbines that the wind turbines are not serviced and therefore are not in operation causing economic losses.

In the case of WDD systems being a mixture of electricity and water production with the operational complexity connected to this, it is even more important to have organised a professional and capable organization of the operation of the WDD systems.

As a principle it is suggested that the partner responsible for operating the WDD systems is paid by the success of the operation of the WDD system. In this way there is a motivation for successfull operation of the WDD systems.

Different models for operation of WDD systems can be suggested. Operation of the WDD system can be connected to the model of ownership of the WDD system, but not necessarly.

5.4.2 Models for organising operation of WDD systems

Different models for organising operation of WDD systems can be proposed:

<u>The BOOT/BOO-model:</u>
The BOOT/BOO-model leaves the responsability of operation of the WDD systems at the supplier of the WDD system. The supplier of the WDD system are expected to have the technical capacity of operating the WDD system. The supplier will have to find a local partner, who in practise can take care of the operation of the system. Another solution can be that the supplier employes local people to take care of the operation.

<u>Servicing and operating companies:</u>
Private companies can specialize in servicing and operating WDD systems. The private companies can be co-owners of the WDD plants or just act as commercial companies paid by the owners of the WDD systems.

This can be a good solution, if the servicing and operating company has the technical capacity and by payment through successfull operation has the motivation for successfull operation.

<u>Local communities:</u>
In many cases the local communities do not have the technical capacity to operate the WDD systems. In general it can be difficult to have a quickly operating servicing company in a context of a local community/municipality with slow decision making procedures.

<u>Power utilities:</u>
If the local power utilities are motivated for operating a WDD system, it can be a solution that they handle the operation of the WDD systems.

5.5 Financing of WDD systems

5.5.1 General comments

Financing is in principle connected to all the elements of establishing and operating the WDD systems. In the following is mentioned some of the key issues, which are in focus considering financing of projects. These key issues are put into relation to the financing of WDD systems.

5.5.2 Product characterization

The technological basis of the product is described. To what extend is the product technically developed. Are there any licenses connected to the product. How does the product relate to other systems. What is the weakness of the product compared to other similar products.

The main components of WDD systems, wind turbines and desalination systems are technically well known and have demonstrated that they technically can function. But in the financial world wind turbines to some extend are still considered to be some how "exotic". This means that the more complex and innovative the WDD concepts are made, the more difficult it becomes to finance WDD projects, or the more expensive it is to finance these WDD projects.

The technically and orginsationally most simple way of defining WDD systems as desalination systems, where electricity is provided by wind turbines (to the grid) providing the electricity consumption of the desalination system to a lower price, is in principle the easiest WDD system to finance. The more technically unproven and complicated, the more difficult to finance.

5.5.3 The market

There shall be a market for WDD systems or for the products of the WDD systems, water and eventually electricity. Having a market means that there shall be a demand for the products of the WDD systems, and the buyers shall be able to define, what they are willing and able to pay for water (and electricity). Definition of the water price can be a problem, because the short time marginal price for water can be small, while the long term marginal costs can be very high due to detoriation of the local water resources. Finding the right price for water in this case easily becomes a political issue with the difficulties this can cause.

Normally supply of water is taking place through municipal or similar organisations. But as described above these organisations in many cases can not be expected to take initiative to establish WDD systems. This means that in many cases private developers of WDD systems will operate in a context, which is normally not functioning on market premises. This can lead to difficulties in establishing a clear market situation with a supplier of water (and electricity) and buyers of water, knowing what price they want to pay. It can therefore be difficult to define the real market.

WDD systems are relatively new products. This means that there are no specialized suppliers of such systems. This lack of suppliers targeting supply of WDD systems makes it more difficult to have an efficient marketing af WDD systems.

5.5.4 Production and operation

The lack of a sector of suppliers of WDD systems also means that the production of WDD systems is not systematically organised. If a market of WDD systems will be established it must be foreseen that the production of these systems can be better organised leading to lower prices.

As mentioned above an efficient organisation of the operation of WDD systms is crucial for obtaining financing of WDD systems. This question of operation must be handled efficiently.

5.5.5 Management team

From a financing point of view the single most important issue is the management team. To a great extend, investments are dependent on the people involved just as much as on the concepts and the strategies.

In many cases it is a problem to establish a good management team for establishing and/or operating the WDD systems. Many times there is a lack of qualified and motivated local people.

On way of solving this problem and bring the management problem under more control is to establish the WDD systems as BOOT/BOO. This means that the suppliers of WDD systems themselves can control the management situation. If this solution shall be a success, it means that the suppliers of WDD systems shall be able to establish efficient management teams.

Education activities by the suppliers, governments or others can contribute to improve the situation concerning management.

5.5.6 Risks and stratetic issues

From a financing point of view reducing the risks is a crucial point. Different arrangement can be made for reducing the risks, including guarantee arrangements by local, regional or national public authorities.

The risks can be of different character, as for example:

<u>Technical risks</u> - meaning that simple, well proven and reliable WDD solutions will be preferred from a financial point of view.

<u>Operational risks</u> - meaning that an efficient operational organisation and solution must be established as described above. One of the issues connected to this element is to minimize the operation costs.

<u>Financial risks</u> - in general there are financial risks connected to technical, operational risks etc. Supplementary to this, there can be the risk that payments for supply of water are not made.

The political regulation of especially the electricity market gives a potential financial risk that regulations concerning establishment of wind turbines and independent electricity production can be changed meaning that there is a risk that profitability of WDD projects are reduced. These types of risks mean that investors can be reluctant to participate in WDD projects.

5.5.7 Financial performance

As demonstrated in other sections of this report WDD systems can in areas with good wind conditions be profitable.

In the areas of the European Union, where WDD systems are of great interest, funding from the EU Structural Fund is a possibility. Support of typically 40-50% of the total investment influences to a great extend the financial performance of WDD systems, if such grants can be achieved.

5.5.8 Resource requirements

The total resource requirements for establishing and operating WDD systems must be estimated in terms of capital and personnel.

5.5.9 Concluding remarks concerning financing

By nature the financing systems are conservative, and there is a tendency to prefer a simple WDD solutions from a technical and economical as well as an organisational point of view.

5.6 Concluding general remarks concerning implementation of WDD systems

It must be stressed that general recommandations can rapidly change due to the fact that the "WDD sector" is in it´s initial stages, where new experiences can change the picture.

It must also be kept in mind that in this study focus has been on potential WDD project initiatives in a relatively small scale for smaller islands. Other conclusions might be drawn for bigger WDD project initiatives for big communities. On the other hand it seems to be more reasonable and less risky to start up with smaller initiatives. Therefore it seems not to be likely that big WDD project projects will be carried out in this initial stage of development.

Using the results from the analysis above the following models for implementation and development of WDD systems are proposed:

<u>A.Implementation context:</u>
In an implementation context WDD systems shall be defined as desalination systems using wind turbines as a tool of making the costs of water production lower.

As a consequense of this approach the WDD systems focused on in an implementation context shall be technical systems, where the desalination system can be seen as an independent part (investment) and the wind turbines can be seen as an independent part (investment).

The ownership and the organisational structures behind the desalination system and the wind turbines are integrated/common. This approach makes it possible to optimize the outputs of the 2 elements together technically and economically.

The EU Structural Fond must in the future specifically target promotion of WDD systems.

<u>B.Development and demonstration:</u>
There is a need of demonstrating and developing technical and energical more optimized WDD concepts, e.g. the concept of utilizing the surplus heat from diesel generators together with electricity from wind turbines for integrated desalination and water production.

Also the strategy of utilising desalination systems for high wind energy penetration should be demonstrated and developed.

It is proposed that these more complex solutions are promoted within the framework of demonstration-and pilot project programmes, European and/or national programmes. It is recommended that in the future WDD solutions have a high priority in the European Thermie- and Joule Programmes.

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Final Report

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Abstract (Max. 2000 char.)

The present report is the summary report for the APAS-project '*Feasibility Studies on Combined Wind Diesel Desalination in Greece and Spain*' supported by the European Commission, DG XII, under contract no. RENA-CT94-0006.
The project consists of two feasibility studies: Paros, Greece and Menorca, Spain. The purpose of the studies is to investigate the feasibility of combining wind energy and fresh water production in diesel powered grids. The results of the two studies are in the reports: Risø-I-1042 (Paros) and Risø-I-1043 (Menorca).
The major finding is that there are technical and economical benefits from combining wind energy with desalination plants. The penetration level can be increased without increase in the amount of dumped wind energy and a large proportion of the energy required by the desalination plant can be covered by wind energy.
The wind resources in Paros are very good. A publicly or privately owned system that combines wind energy and desalination units is economically very attractive because of the legal framework concerning renewable energy in Greece. Efforts are underway to implement a system by combining private and public investors.
In Menorca the wind resources are not as attractive as in Paros and the available energy cheaper. Wind energy is therefore not feasibible when only avoided fuel costs are considered. However, due to environmental concerns the local authorities and utility are interested in an integrated wind diesel desalination system. Another reason for that interest is a wish to participate in the development of such systems. Support for such a system is sought mainly through EU.

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